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LANDSAT-2 SATELLITE FOLLOW-ON INVESTIGATION No. 28790
AGRICULTURAL RESOURCES INVESTIGATIONS IN NORTHERN ITALY AND SOUTHERN FRANCE
(AGRESTE PROJECT)

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Fourth Progress Report

28790

May 15th – December 31st, 1976

Commission of the European Communities
JRC - Ispra Establishment

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Fourth Progress Report

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PART I

ACTIVITY PERFORMED ON THE ITALIAN TEST–SITES

LIST OF INSTITUTES AND ORGANISATIONS INVOLVED IN THE RESEARCH

• Biology Group - Ispra of Directorate for Science and Education	BGI
• Centro Applicazioni Tecnologie Avanzate - Napoli	CATA
• Ente Nazionale Risi - Mortara	ENR
• Institut für Physikalische Weltraumforschung - Freiburg	IPW
• Istituto per la Geofisica della Litosfera - Milano	IGL
• Istituto Nazionale delle Piante da Legno - Torino	INPL
• Istituto di Patologia Vegetale dell'Università - Milano	IPV
• Istituto Sperimentale per la Cerealicoltura - Vercelli	ISC
• Istituto di Sperimentazione della Pioppicoltura - Casale Monferrato	ISP
• Joint Research Centre - Ispra	JRC

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SUMMARY

OF THE ACTIVITY AND ITS RELEVANT RESULTS

Some interesting results have been obtained both from spectral reflectance measurements of diseased and healthy lysimeters and comparison between measured spectra and spectra calculated using the Suits' canopy model. It has been found experimentally that "giallume" produces higher reflectance in the $(0.55 - 0.70)\,\mu m$ region of the spectrum. This was detected with the EG &G spectroradiometer in spite of the fact that the disease was not widely diffused (7% of clerotic leaves).

The Suits' model was applied to the same lysimeters and all the features of the measured spectrum were well reproduced in the calculated one. As an extension of the investigation with the Suits' model a linear correlation was found between reflectance in LANDSAT band 5 and the disease level (a disease diffusion of up to 50%).

The specific experience of CATA on captive low altitude balloons and that of ISP and JRC on poplars were combined to set up a methodology for performing radiometric measurements on trees from a low altitude R.S. platform. The technique was tested on the ISP-controlled experimental poplar farm at Frassineto. This combined use of captive balloon and mobile recording unit has proved itself to be an efficient, flexible and precise tool for tree-signature measurement.

The processing of the considerable amount of data from the 1975 campaign on JRC lysimeters has been completed. The vegetation structure of rice was investigated and interpreted in dynamic terms as a significant factor governing the distribution of solar energy throughout the canopy and therefore conditions the final yield. The radiometric characteristics of the rice culture have been described for the various stages of development, in relation to the vegetation structure in an attempt to establish correlations between data of total biomass and of grain yield.

A preliminary study has been done over a test area (acreage roughly 3 km^2) to investigate the possibility of discriminating between rice varieties using airborne scanner data (11 channels, ground resolution 3.8 m). The first qualitative classification results obtained are encouraging although the discrimination achieved is far from complete; improvements have to be made to the sampling procedure and the atmospheric correction technique and more powerful classifiers will be tested. Preliminary results on the classification of natural beech forests in mountainous regions are also presented. A quantitative comparison between results and ground truth is not yet available but it has been found that most of the beech areas are correctly identified and distinguished from chestnut woods present in the same area.

1. INTRODUCTION

The activity reported here (May 15-December 31, 1976) is a continuation of the preceding one, carried out by the Joint Research Centre-Ispra on the Italian test sites, following the LANDSAT-2 launch, in collaboration with the Biology Group of the Directorate General for Science and Education and the Italian Institutes and Organizations in the context of the LANDSAT-2 follow-on investigation no. 28790 (AGRESTE Project).

An AGRESTE Delegation (PI and two technical Managers for the French and Italian test sites respectively) were invited by NASA to the GSFC to present the results obtained by the JRC and the collaborating Institutes (October 18, 1976).

2. LANDSAT-2 IMAGERY FOR THE MADAGASCAR TEST SITE

The situation, as regards the availability of LANDSAT-2 scenes obtained over our test site between 12-1-1975 and 31-7-1976, is the following:

1. With the exception of one, all the scenes that fulfilled the required conditions (i.e. overlapping the chosen area bounded by $17^{\circ} \leqslant$ latitude S $\leqslant 18^{\circ}$, $\leqslant 48^{\circ}$ longitude E $\leqslant 49^{\circ}15'$; cloud cover $\leqslant 60\%$) were received as black and white transparencies from ASCS Salt Lake City. They are listed in Table 1, with parameters used from the catalogues published monthly by GSFC.

Table 1 : Madagascar scenes available by NASA

Observ. ID.	Long.E	Lat.S	Cloud cover (%)	Date acquired
(a) 2320.05595	49.26	17.17	50	12/8/75
(b) 2375.06053	47.34	18.44	40	2/1/76
(c) 2392.05585	49.21	17.18	50	2/8/76
(d) 2392.05592	49.00	18.45	50	2/8/76
(e) 2465.06022	48.04	17.15	40	5/1/76
(f) 2465.06025	47.43	18.41	40	5/1/76
(g) 2500.05561	49.08	18.37	20	6/5/76
(h) 2501.06013	48.04	17.12	20	6/6/76
(i) 2501.06020	47.42	18.38	20	6/6/76

2. Positive prints of the scene received, enlarged to scale 1:700,000, were studied very carefully. The result was twofold:

   2.1 The test area in which all the ground truth work has been done is located in the vicinity of the town Ambatondrazaka (a A'londra-zaka), the coordinates of which are lat. 17°50´S, long. 48°25´E. It does not appear in the scenes labelled (b), (d), (f), (g), (i).

   2.2 The test area is included in the scenes labelled (c), (e), (h), but it is entirely covered by clouds.

3. The scene labelled (a) was not received at the JRC-Ispra. An inquiry was made on February 15, 1977 to ASCS Salt Lake City, but from an examination of the picture-centre coordinates, it is doubtful that our test area is included in this scene.

4. At this present stage therefore no usable scene is available.

5. A request was made to EROS Data Centre on February 2, 1977, for a listing of all the scenes available which contain Ambatondrazaka, even with cloud cover of up to 100% and of whatever quality, acquired by LANDSAT-1 or -2 from the launch of LANDSAT-1 to July 31, 1976. All scenes available - except those already received - will then be ordered by the JRC as B&W transparencies, so that any possibility, even a very small one, to obtain usable data, will be taken into account.

6. Coverage of our test area by LANDSAT-2 requested from and accepted by NASA for the periods of February and April/May, 1977 in the hope of obtaining usable data.
   The April/May period seems to be more favourable from the point of view of cloud cover but the February period is necessary to achieve an accurate inventory of the rice (presence of water).

7. There is not much sense, at this stage, in commenting on the work still to be done in the context of LANDSAT data-processing, in view of the complete lack of data.

3. ACTIVITY PERFORMED OVER THE RELEVANT PERIOD

3.1 Research Objectives and Task Distribution

During the fourth research period of the AGRESTE Investigation, activity has been directed towards the following objectives:

a) Rice Investigation:

Processing and interpretation of spectroradiometric data taken on rice lysimeters:

- to correlate reflectance with biomass and yield for different rice varieties and fertilization levels,

- to evaluate detectability by satellite of diseased rice under open field conditions.

Development of some reference ground truth thematic maps.

b) Forest Investigation:

Methodological preparation of a forest signature measurement technique using R.S. captive balloons (test site no. 1).

c) Computer-aided interpretation of aircraft and satellite data:

Discrimination of rice varieties from MSS aircraft data (test site no. 1);

Classification of natural beech forests (test site no. 3).

Task distribution is summarized in Table 2.

3.2 Rice Investigation

3.2.1 Detectability Evaluation of Diseased Rice by Means of Spectroradiometric Techniques

3.2.1.1 Spectroradiometric Measurements on Some Rice Lysimeters

Following the encouraging results obtained from the AGA Thermovision campaign on some rice fields affected by a typical rice disease called "giallume" (see 1st QPR, 2.2.2.2) some measurements have been performed at the JRC-Ispra, in collaboration with IPW, using a continuous wavelength variation spectroradiometer EG&G, range (0.4 - 1.0) μm. The purpose of this experiment was the investigation of the spectral behaviour of some controlled rice lysimeters where the "giallume" was deliberately inoculated.

The disease was introduced into the lysimeters by means of a flying vector at the end of June. Radiometric observations were performed from July 7 to 15, when it was expected that the disease would diffuse in the lysimeter.

Continuous spectral reflectances of different lysimeters on different days were obtained as well as reflectances in the four LANDSAT channels. The disease did not attack all the infested lysimeters. Only one, presenting 7% of clerotic leaves can be considered in the present investigation to be really affected by "giallume".

In Fig. 1 the spectral reflectance of lysimeter no. 18, which was attacked by disease (continued line) and that of lysimeter no. 19, which was not attacked by the disease (dashed line), are shown at the beginning (thin line) and at the end (thick line) of the measurement campaign.

As a result of this investigation, it can be seen that the lysimeter infested by "giallume" (no. 18) has a higher reflectance in the VIS (0.55-

3a

Table 2 : Task distributions among the AGRESTE–CO–Investigators

	Specific Objectives	CATA	ENR	IPW	INPL	IPV	ISC	ISP	JRC	BGT
Rice Investigation	Detectability evaluation of diseased rice areas from aircraft and/or satellite			Spectroradiometric measurements and interpretation under lysimetric conditions		Diseased lysimeters preparation			Spectro-radiometric measurements and interpretation under lysimetric conditions	
	Extrapolation to open field conditions by comparing calculated and measured spectra			Applicability demonstration to rice cultivation for multilayer canopy model					Applicability demonstration to rice cultivation for multilayer canopy model	
	Correlating rice reflectance with fertilization levels, density of sowing, varieties and agrobioclimatological parameters under lysimeter conditions									Spectral and conventional data processing and interpretation
	Determining influence of atmospheric path on spectral signature and correcting for it		Agrobioclimatological data preparation.				Agrobioclimatological data preparation			Data processing and interpretation
	Ground-truth preparation		Improving, producing and/or interpreting partial maps (satellite and aircraft)		Interpretation of photographic maps (satellite and aircraft)				Preparation of reference maps	
Forest	Determining forest spectral signature	Methodological preparation of a R.S. captive balloon system						Contribution to the methodological preparation	Contribution to measurement methodology assessment	
	Ground-truth preparation				Interpretation of photographic maps			Interpretation of photographic maps		
Aircraft and satellite data processing and interpretation	Software preparation									Development of an interactive software package for colour CRT display. Development of utility and data processing programs
	Classification and inventory		Aid to interpretation							Computer-aided interpretation of airborne scanner data. Discrimination of rice varieties
					Aid to interpretation					Computer-aided interpretation of satellite data. Classification of natural beech forests

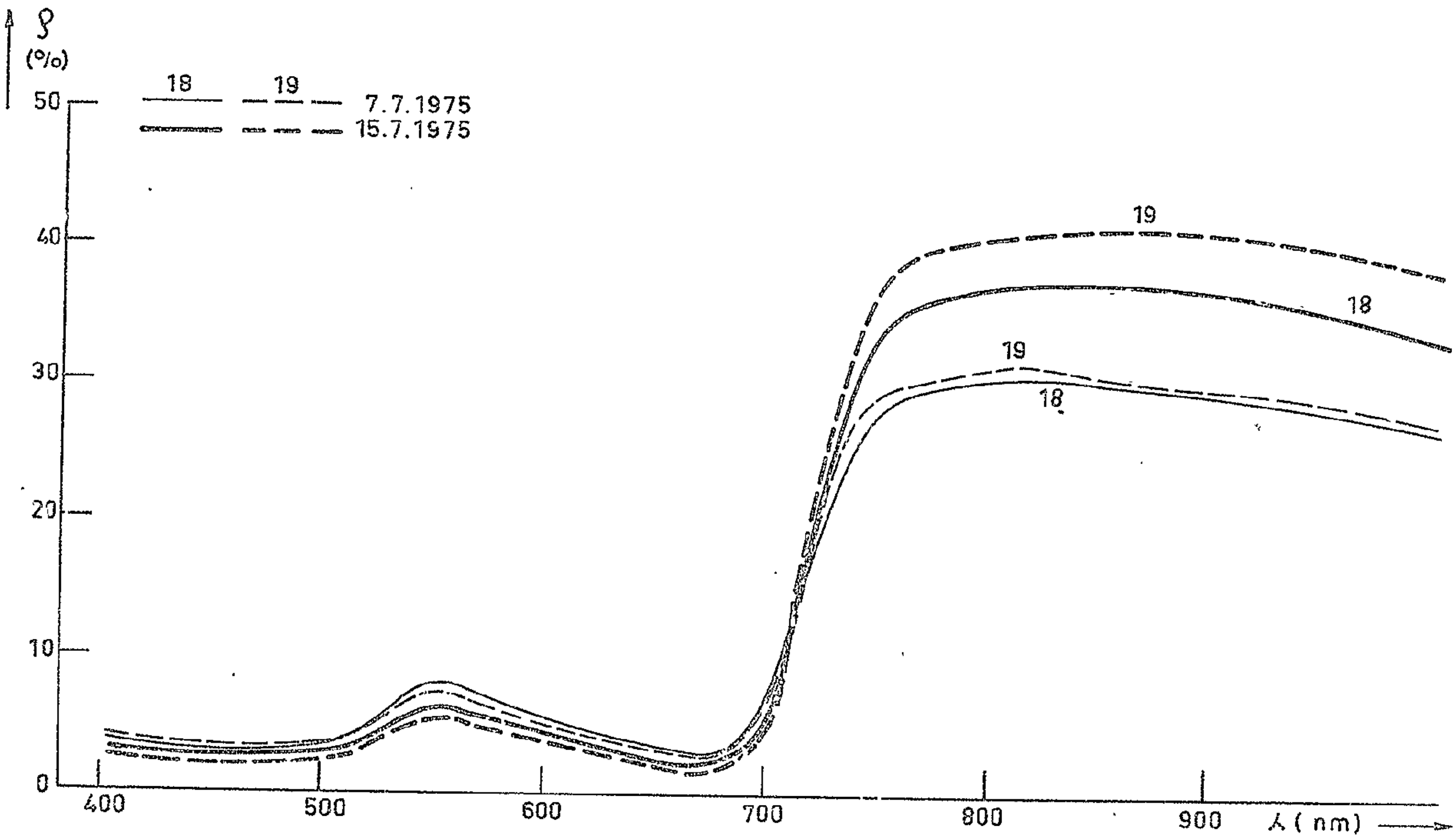

Fig.1 MEASURED SPECTRAL REFLECTANCE OF RICE LYSIMETERS n° 18 and n° 19

3B

0.7) μm region and a lower one in the NIR region than that of a non-infested lysimeter (no. 19). These results are also reported in Table 3 where the integral reflectances on the four LANDSAT bands are shown for four lysimeters, of which only the no. 18 one was attacked by "giallume".

Since there was some doubt as to whether the lysimeter affected by only 7% of clerotic leaves would be representative of the "giallume" phytopathological behaviour for a more extended percentage of the disease for rice cultivation, it was decided to use the Suits' canopy model to obtain this information.

3.2.1.2 Theoretical Investigation Using the Suits' Canopy Model

3.2.1.2.1 - Introduction

The Suits' model[1] gives the directional spectral reflectance of a vegetative canopy. It is based on both geometric and spectral characteristics of individual components of the considered canopy.
Input data for the mathematical model are:

1. The number of infinitely extended horizontal canopy layers, where components are randomly distributed and homogeneously mixed.
2. The surface index of plants related to the horizontal and vertical components of leaves.
3. The optical properties of different components of the considered plant (namely diffuse reflectance and transmittance of leaves, stalks and panicles) which are measured in the laboratory.

3.2.1.2.2 - Comparison of Computer Evaluated Spectra and EG&G Measured Spectra

The spectral reflectance for a healthy rice lysimeter, measured with the EG&G spectroradiometer, has been compared with the reflectance calculated by means of the Suits' model starting from both the geometric and spectral characters of individual components of rice plants. The latter have been measured by means of a Cary 14 Lab. spectrometer and the results are reported in Table 4 and in Figs. 2 and 3. Input data for the Suits' model were measured in parallel with radiometric measurements. The sun zenith-angle of 30°, the angle of view of 0° from the vertical and the azimuthal angle of 90° are the same as those of the measurements performed using the EG&G spectroradiometer.

The results of this comparison are shown in Fig. 4.

Analogous comparison has been made for the lysimeter with 7% of leaves which are clerotic due to the effect of the disease. The results

Table 3 : Reflectance in Landsat bands 4, 5, 6, 7 for lysimeters 17, 18, 19, 20

7,11,15/7/75		Band 4	Band 5	Band 6	Band 7	Band 7/ Band 5
Lys.17	7.7.75	0.0570	0.0535	0.2631	0.3083	5.7626
	11.7.75	0.0574	0.0528	0.2839	0.3398	6.4317
	15.7.75	0.0478	0.0455	0.3324	0.4329	9.5212
Lys.18	7.7.75	0.0628	0.0570	0.2500	0.2935	5.1507
	11.7.75	0.0657	0.0590	0.2708	0.3282	5.5577
	15.7.75	0.0534	0.0518	0.3036	0.3756	7.2562
Lys.19	7.7.75	0.0686	0.0542	0.2590	0.3006	5.5431
	11.7.75	0.0590	0.0510	0.2867	0.3404	6.6713
	15.7.75	0.0458	0.0432	0.3177	0.4086	9.4574
Lys.20	7.7.75	0.0595	0.0524	0.2453	0.2905	5.5464
	11.7.75	0.0560	0.0471	0.2616	0.3185	6.7559
	15.7.75	0.0441	0.0431	0.3365	0.4264	9.8996

Table 4 : Geometric characterization of lysimeters N.18 and 19 (8/7/75)

Lysimeter N. 18

			X = −14.00,	−23.00	
S CLASS	I	0.05565	0.05928	0.05286	0.04725
S CLASS	II	0.00419	0.00446	0.00398	0.00356
S CLASS	III	0.0	0.0	0.00426	0.01970
S CLASS	IV	0.0	0.0	0.0	0.0

Lysimeter N. 19

			X = −17.00,	−25.00	
S CLASS	I	0.07173	0.09147	0.06813	0.07804
S CLASS	II	0.0	0.0	0.0	0.0
S CLASS	III	0.0	0.0	0.00487	0.02205
S CLASS	IV	0.0	0.0	0.0	0.0

Note:

X	level of layers (cm)
CLASS I	horizontal and vertical LAI of healthy leaves
CLASS II	horizontal and vertical LAI of deseased leaves
CLASS III	horizontal and vertical LAI of stalk
CLASS IV	free

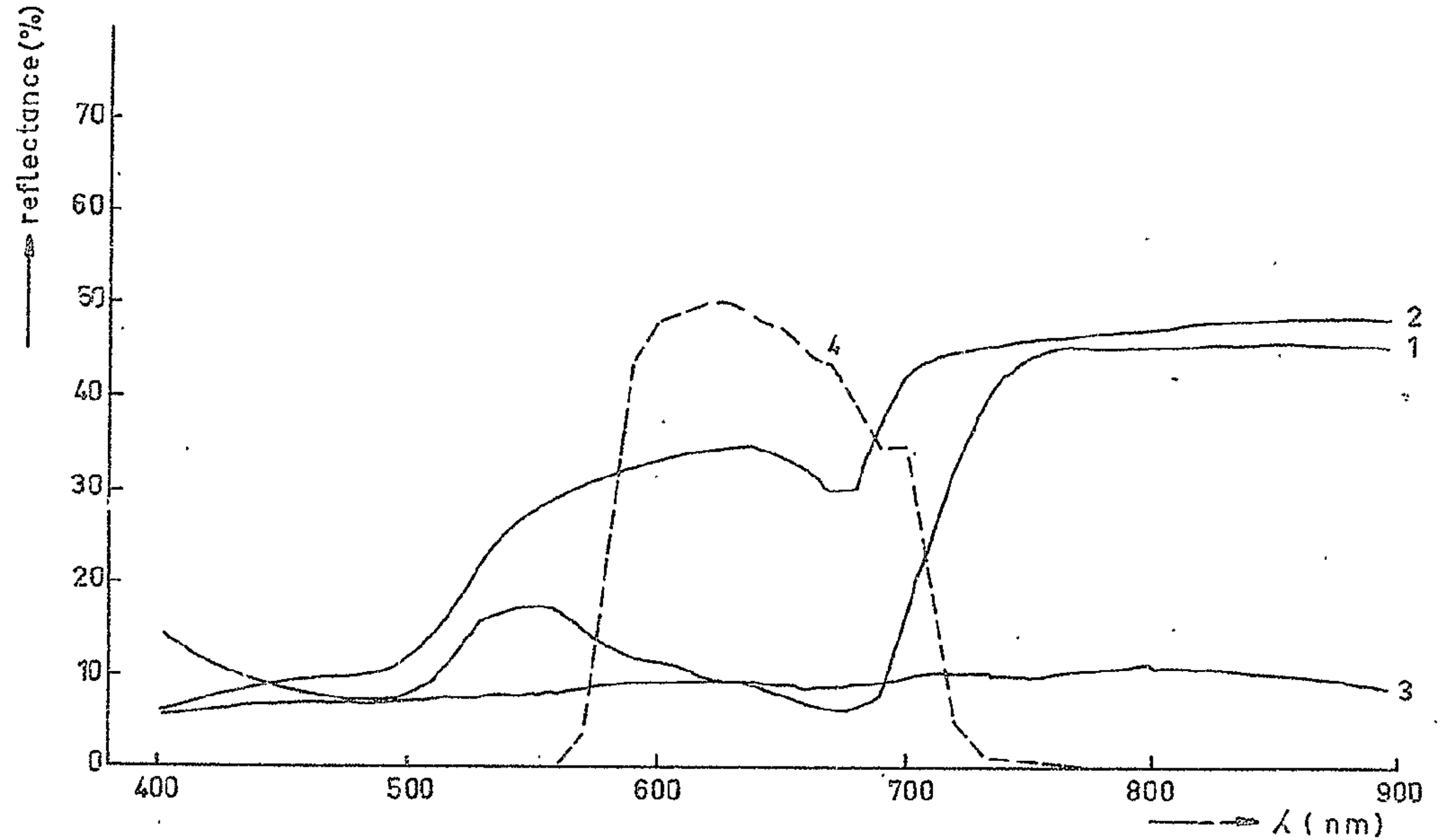

Fig. 2 DIFFUSE REFLECTANCE OF 1) green leaves 2) yellow leaves
3) water 4) band-pass of LANDSAT band 5

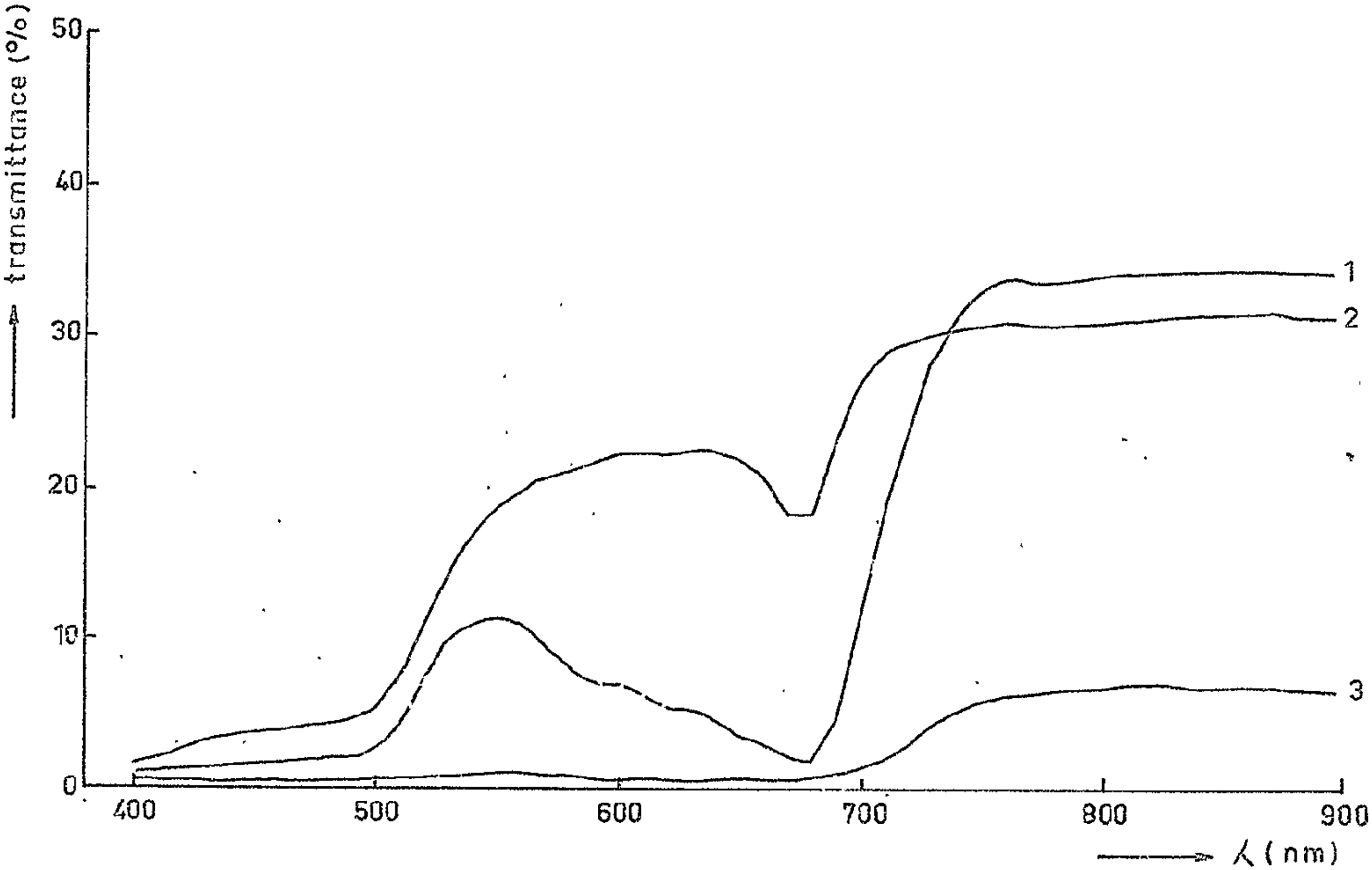

Fig. 3 TRANSMITTANCE OF 1) green leaves 2) yellow leaves 3) stalk

4c

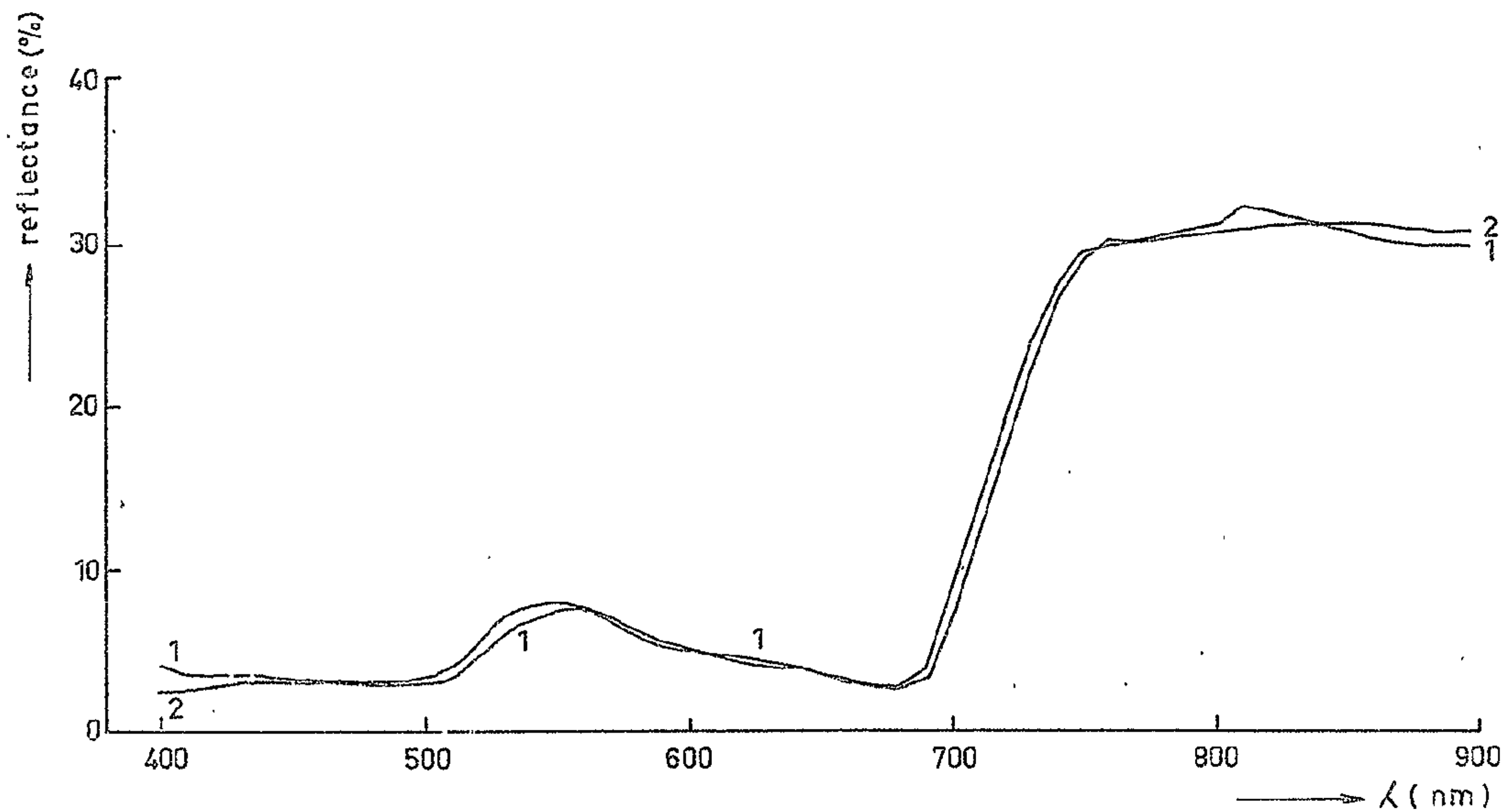

Fig. 4 COMPARISON BETWEEN CALCULATED REFLECTANCE (2) AND RADIOMETRIC MEASUREMENT OF REFLECTANCE (1), DISEASE 0%

are shown in Fig. 5.
In both cases the agreement among the relevant curves is quite satisfactory. All the features of the measured spectra are very well reproduced in the calculated spectra. Therefore it has been possible to state that the Suits' canopy model may be applied to evaluate the reflectance of a rice field with a high level of confidence.

3.2.1.2.3 - Extrapolation to Situations with more than 7% of Clerotic Leaves

The model, after being checked, has been used to extrapolate the reflectance behaviour of a diseased rice field over 7% of clerotic leaves. Reflectance was calculated as a function of "giallume" for 0%, 7%, 15%, 30%, 60%, 100% of clerotic leaves.

This study has demonstrated that the highest discrepancy in the shape of the spectral reflectance curves due to different level of disease attack is found in the region (0.54 - 0.68) µm. Since the band 5 of the LANDSAT Satellite is located approximately in this region, an attempt has been made to correlate between reflectance from the zenith in band 5 and the level of disease attack. The results of this correlation are shown in Fig. 6, where it may be seen that a linear correlation exists up to approximately 50% of diseased leaves.

Further investigation on open-field conditions are needed to check the detectability by LANDSAT satellites of "giallume" as a variation of reflectance in band 5. This hypothesis requires an epidemic diffusion of disease.

This verification has not yet been possible owing to the absence of a diffuse disease attack on test site no. 1.

3.2.2 Application of Suits' Model to Some Typical Radiometric Problems for Rice

A further extension of the Suits' model application to the present study was made to study the directional reflectance of a rice field as a function of the sun-zenith angle θ, the view angle Φ, the azimuthal angle ψ and the characteristics of sunlight (direct or diffuse). The aim of this extension was to find the best-fitting conditions both for MSS flights and radiometric ground truth measurements. The optical and geometric properties of rice plants used in the model for the present study, are those measured on healthy rice lysimeters at the beginning of July. The following results are therefore only valid for the corresponding growth state of rice:

- for a sun-zenith angle $\theta \approx 20^{\circ}$ reflectance ρ of vegetative canopy is almost invariant as a function of the view angle Φ and the azimuthal angle ψ,

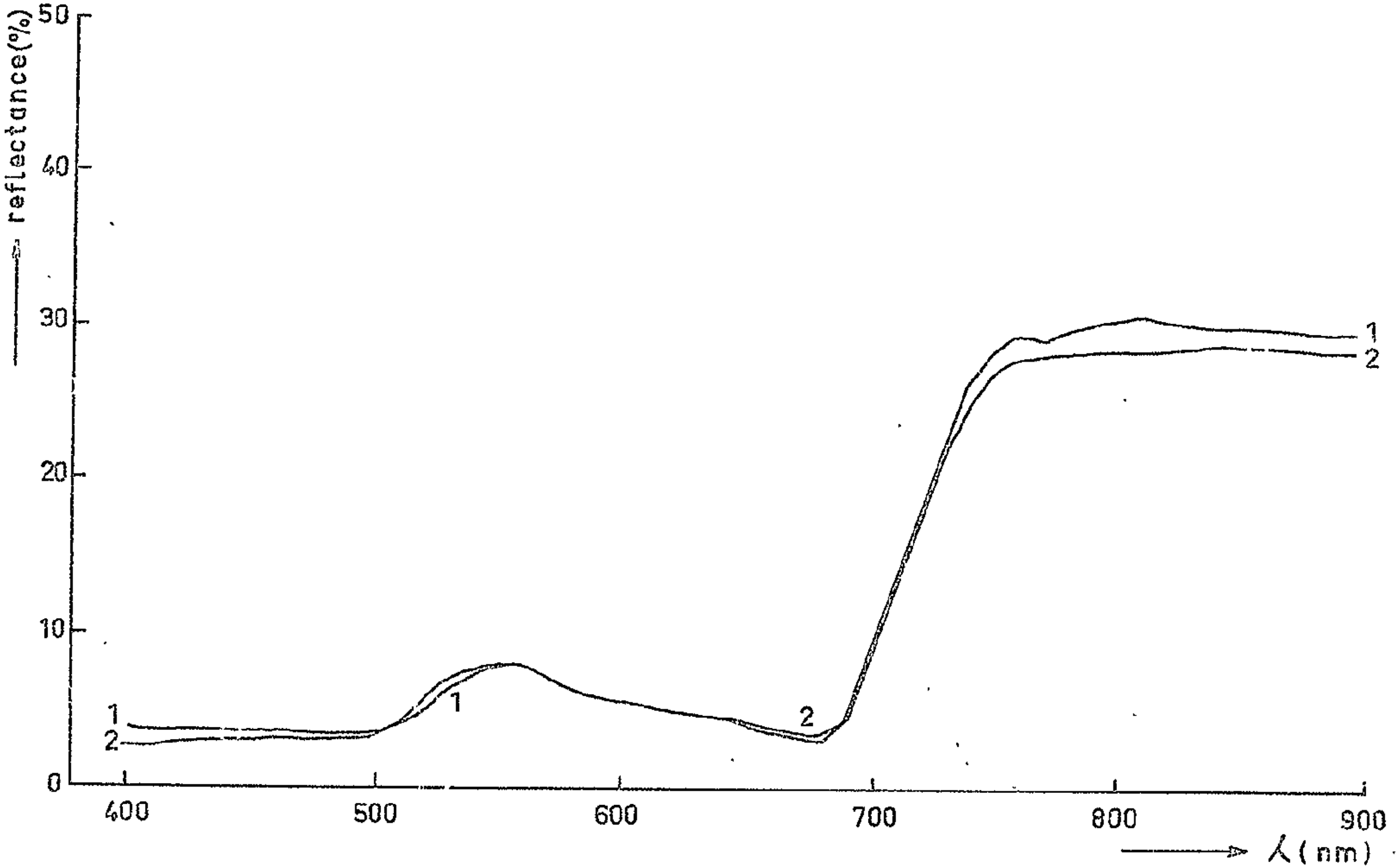

Fig. 5 COMPARISON BETWEEN CALCULATED REFLECTANCE (2) AND RADIOMETRIC MEASUREMENT OF REFLECTANCE (1), DISEASE 7 %

5a

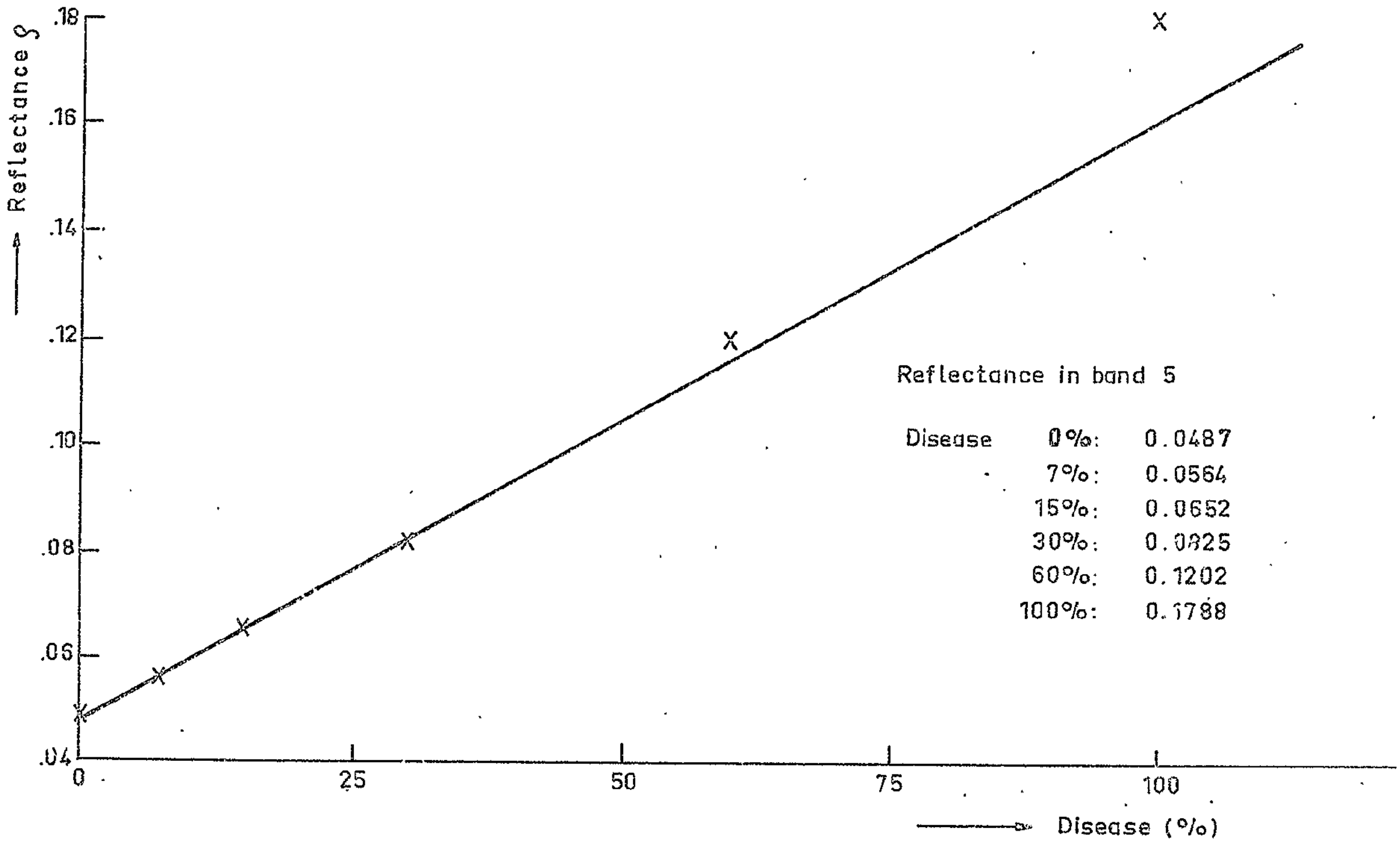

Fig. 6 REFLECTANCE IN LANDSAT BAND 5 AS A FUNCTION OF DISEASE LEVEL

- radiometric ground truth measurement may be performed with a view angle $\phi \approx 15^{o}$ in order to maintain reflectance ρ invariant with a change in θ during the day,
- reflectance ρ of vegetative canopy is not invariant with a change in sunlight characteristics (direct or diffuse).

3.2.3 Reflectance Measurement Campaigns on Rice Lysimeters

Processing of the numerous data of the 1975 campaign on JRC-lysimeters has been completed. It concerns three different sets of 5 lysimeters cultivated under the following conditions:

1. density 64 plants/m^2 at planting, per groups of 4 plantlets; 1 single addition of N-fertilizer (120 units),
2. planting at the same global density but plant by plant; same N-fertilization,
3. as in 2 but N-fertilizer distributed 2/3 at planting and 1/3 at early ripening.

The specific aim of the experiment was to investigate the vegetation structure as a significant factor governing the distribution of solar energy through the canopy and hence conditioning the final yield, with an attempt to establish correlations with radiometric measurements.

Vegetation structure is interpreted in dynamic terms as the result of the competition amongst tillers which occurs at different developmental stages of the rice plant and where two limiting factors of the environment are mostly concerned: availability of nitrogen and radiant energy. Planting in groups of plantlets (treatment 1) causes an immediate and precocious competition between plantlets with a consequent detrimental effect on the number of tillers. At the end of tillering, an intense competition between "major" and "minor" tillers takes place, which means that the further development of minor tillers can proceed only where there is a sufficient supply of N and light. The resulting vegetation structure conditions the final yield. Therefore the supplementary availability of N at the beginning of the ripening stage (treatment 3) causes the rehabilitation of tillers which would normally have disappeared, and a vegetation structure more favourable to grain production.

An accurate analysis of the agronomic data (dry weight and frequency distribution of tillers, tiller density, total leaf index and cumulative leaf index at several canopy layers) that allows classification of the vegetation structure of the three treatments according to their production potential, with treatments 1 and 3 being the least and most favourable, respectively.

These differences in vegetation structure lead to significant differences in reflectance between the 3 treatments, both in the near IR (channel 6) and in the visible light (channel 4), in spite of a similar general evolution in time. This evolution is characterized by a maximum reflectance in the near IR 50-60 days after planting, close to the peak of the leaf index, and by a general decrease of the reflectance in the visible range during the formation of the vegetation structure, until a minimum is reached at the end of earing (about 80 days after planting). The ratio ρ_6/ρ_4 exhibits the typical evolution described in earlier reports with a peak occurring in the middle of earing around 70 days after planting.

A rough correlation can be found between these peak values of the ratio ρ_6/ρ_4 and the respective grain yield of treatments 3 and 2 (542 and 483 g/m^2 respectively). The displacement in time of the peak value of the ratio in treatment 1 does not allow generalization of such a correlation (yield as low as 436 g/m^2 as a result of a less favourable vegetation structure). On the other hand, the limited number of 5 duplicates inside each treatment is insufficient to establish a significant correlation with the grain yield. It must be pointed out that no single correlation between radiometric data and grain yield is likely to be valid without taking into account the analysis of the vegetation structure and of its development in relation to the limiting environmental factors. The variable availability of N in the lysimeter experiments illustrates this point very clearly if the availability of N is not excessive and occurs at an adequate stage of development (at the beginning of the ripening stage as in treatment 3), the potential of production will be oriented towards an increased total biomass, positively correlated to the radiometric data and to the final grain yield. On the contrary, excess of N or an inadequate vegetation structure will cause a decrease of the yield coefficient (ratio of the dry weight of panicle to the dry weight of total biomass), thus orienting the productive potential towards production of vegetative material, causing at the same time a shift in the correlation of the grain yield with radiometric data.

3.2.4 Ground Truth Preparation

The ground truth map to the south of Mortara (see 3rd QPR, 3.2.4) has been improved, in collaboration with ENR, in order to report on some additional interesting targets (water logged meadows, corn, poplars, grass, etc.) for computer-aided classification purposes. Eleven different rice varieties have already been distinguished. This map will become the foundation document for the discrimination studies on rice varieties, using Bendix airborne scanner data (see 3.4.3).

Work on drawing-up a ground truth map has reached an advanced stage, but only on rice as a whole, and on a much larger area between Mortara and the Po-river (test site no. 1).

3.3 Forest Investigation

3.3.1 Methodological Setting-up of Forest Signature Measurement Using R.S. Captive Balloons

During the present intensive phase of AGRESTE research on forest classification, it has been found to be useful to have exhaustive information on the spectral signature characteristics of poplar clones and some inventory-concurrent tree species. The need arose for a low altitude R.S. platform, in order to perform radiometric measurements on trees, more specifically on poplar, willow and robinia afforestations.

Since low-altitude captive balloons represent an easily controlled and inexpensive platform, it was decided to combine the specific experience of CATA and the ISP´ and JRC´ investigation on poplars.
With this purpose in mind an experiment was performed in the autumn of 1976 with the aim of checking and setting up this technique at Casale Monferrato (test site no. 1) on the poplar experimental farm of Frassineto, controlled by ISP.

A Delacoste type V.D.4 captive balloon, equipped by CATA´s researchers with an Exotech mod. 100 A radiometer and a remotely motor-controlled Olympus camera for ground truth documentation was positioned at about 80. m above poplar experimental fields.

Radiometric data of reflected irradiance have been sent by cable from the vertically suspended Exotech mod. 100 A to the JRC´s mobile unit on ground. These data were recorded in a Schlumberger 10-channel data logger, in parallel with the data coming from another Exotech mod. 100 A measuring the incoming sun irradiance.

Spectral signature of different poplar clones for LANDSAT bands were automatically obtained by making a simple ratio of the recorded Exotech mod. 100 A data. In this way the joint use of captive balloon and mobile recording unit has shown the entire R.S. system to be an efficient, flexible and precise tool for tree signature measurement.

Owing to both the adverse meteorological conditions and the rather advanced phenological state of poplars it was decided not to make a regular measurement campaign on the ISP experimental area of Frassineto.

A complete series of measurements is envisaged in spring 1977. Spectral signature will be investigated for:

a) Populus alba,
b) Populus deltoide,
c) Populus X euroamericana,
d) Salix alba,

e) Robinia,

which are the three wide clonal classes of poplar and the concurrent arboreous varieties in the AGRESTE Italian test sites.

3.3.2 Ground Truth Preparation for Natural Forest Classification

Ground truth documentation has been prepared by INPL. NIR Aerial photos (scale 1:17,000) taken in 1974 have been interpreted. Some homogeneous zones of beeches, chestnuts and meadows have been singled out. The region under study was that of Cuneo in the Maritime Alps (test site no. 3), i.e.:

a) Valle Stura, between Demonte and Aisone,
b) Vallone dell'Arma, between Demonte and Rifugio Viridio.

3.4 Satellite and Aircraft Data Processing and Interpretation

3.4.1 Implementation of an Interactive Software Package

3.4.1.1 General

In parallel with the main classification and interpretation activity, the development of the interactive software package has proceeded during the period under consideration. A set of new modules has been created, capable of performing the following tasks:

- extraction of statistical data from training areas,
- supervised classification according to 3 different methods,
- level-slicing by ratios of two linear combinations of selected channels,
- file management programs for storage and retrieval of information created or needed during a session.

Most of these programs are in operative condition and some have reached test status. Much care has been taken to obtain a good definition of all data involved in the complete system of interactive programs, in order to ensure flexible cross-over of information between different procedures, ease of extension of existing modules, logical construction of foreseen algorithms and the possibility of the creation of other software interfaces for terminals still to be defined.

3.4.1.2 Colour CRT Display

Since July 1976 a COMTAL 8000 series image processing device has been installed. The present configuration comprises the colour CRT Video, a refresh disk memory for three images of 512 x 512 bytes and for three graphic overlays (1 bit for each point), trackball, control unit with three function memories and a pseudo-colour memory, DEC PDP 11/05 processor with 16 Kbytes of core memory, 45 ips/800 bpi 9-track tape unit. Since the software delivered with the COMTAL unit is rather limited and in particular lacks a true operating system, some additional routines, in particular one for tape input written in the scanner data format used at the JRC, had to be added in machine code of the PDP 11. Also in the batch program MAPEDIT an output format compatible with the COMTAL input format has been added, allowing the representation of map output of any batch program on the COMTAL display unit.

3.4.2 Development and Maintenance Utility and Data Processing Programs

The highly parametric clustering program, CLUSW, has been modified so that on each reclustering cycle, the thresholds on clustering distances and on spatial homogeneity can be changed. The statistical program STATS, has been provided with two additional features, the most important of which is the possibility of printing out the response values of each point in the given test areas in all channels. The algorithm which determines the points belonging to a set of polygons describing a test area boundary, has been redesigned and now works correctly.
The maximum likelihood classifier, PARAM, has been extended to allow the thresholding of each class. Assignment of a point to a class will be inhibited if the membership probability is below the threshold. Also the control cards of the PARAM program have been simplified and made compatible with the other batch programs.
Minor corrections had to be made to several batch programs.

Since tapes of the SKYLAB S 102 13 channel-scanner became available to the JRC and flights with a Bendix 11-channel scanner have been carried out for the AGRESTE Project (see 3.4), a tape reformatting program, COPTRAN, has been written to convert SKYLAB tapes into full and half resolution and Canadian format LANDSAT tapes and Bendix tapes to the format compatible with our batch programs. Optionally COPTRAN performs a correction procedure for the atmospheric effects depending on the scan angle, through a long track averaging and smoothing technique. This procedure improved overall classification and comparison performance especially for short wave channels, but has a tendency towards erroneous behaviour due to local inhomogeneities especially for high contrast infrared channels. An attempt will be made to improve its performance by the use of low order polynomial approximation and/or reflectance gradients of homogeneous areas.

The following features have been added to the program MAPEDIT, for linear geometric correction and map editing.
The input might be any map output of the programs currently in use at the JRC, or any image data in line-interleaved or pixel-interleaved format. One output format has been added (cf. 3.4.2). The coordinates of points in the reference map can be calculated from the corresponding input coordinates.

3.4.3 Computer-aided Interpretation of Airborne Scanner Data

3.4.3.1 MSS Flight Characteristics

A flight was made on August 7, 1975 to acquire data from a Bendix M^2S scanner at a date on which the various rice varieties would be in the flowering stage, considered to be a favourable phenological period for discriminating varieties of rice.

The flight was performed at two altitudes (5000 feet and 13,000 feet) between 9.11 and 10.32 o'clock in the morning. The technical data of the scanner are reported in Table 5.

Table 5 : BENDIX M^2S scanner technical data

Scan angle:		100°	
Roll-compensation:		± 10°	
Geometric resolution		2.5. 10^{-3} radian	
Band characteristics: (Wavelengths in μm)	Channel Nr.	Center	Width
	1	0.410	0.06
	2	0.465	0.05
	3	0.515	0.05
	4	0.560	0.04
	5	0.600	0.04
	6	0.640	0.04
	7	0.680	0.04
	8	0.720	0.04
	9	0.815	0.09
	10	1.015	0.09
	11	11.0	6.0

The resolution of the data is then 3.8 m and 9.9 m for the altitudes of 5000 feet and 13,000 feet, respectively.
Four strips of data were acquired at both altitudes (see Fig. 7). Three of them are located in the AGRESTE test site no. 1; strips 1 and 2 are devoted to the study of rice varieties and strip 3 will be used to investigate the discrimination of poplar varieties and classes of age. The four strips are situated in the Po-valley region, to the west of Milan between the Po- and Ticino rivers.

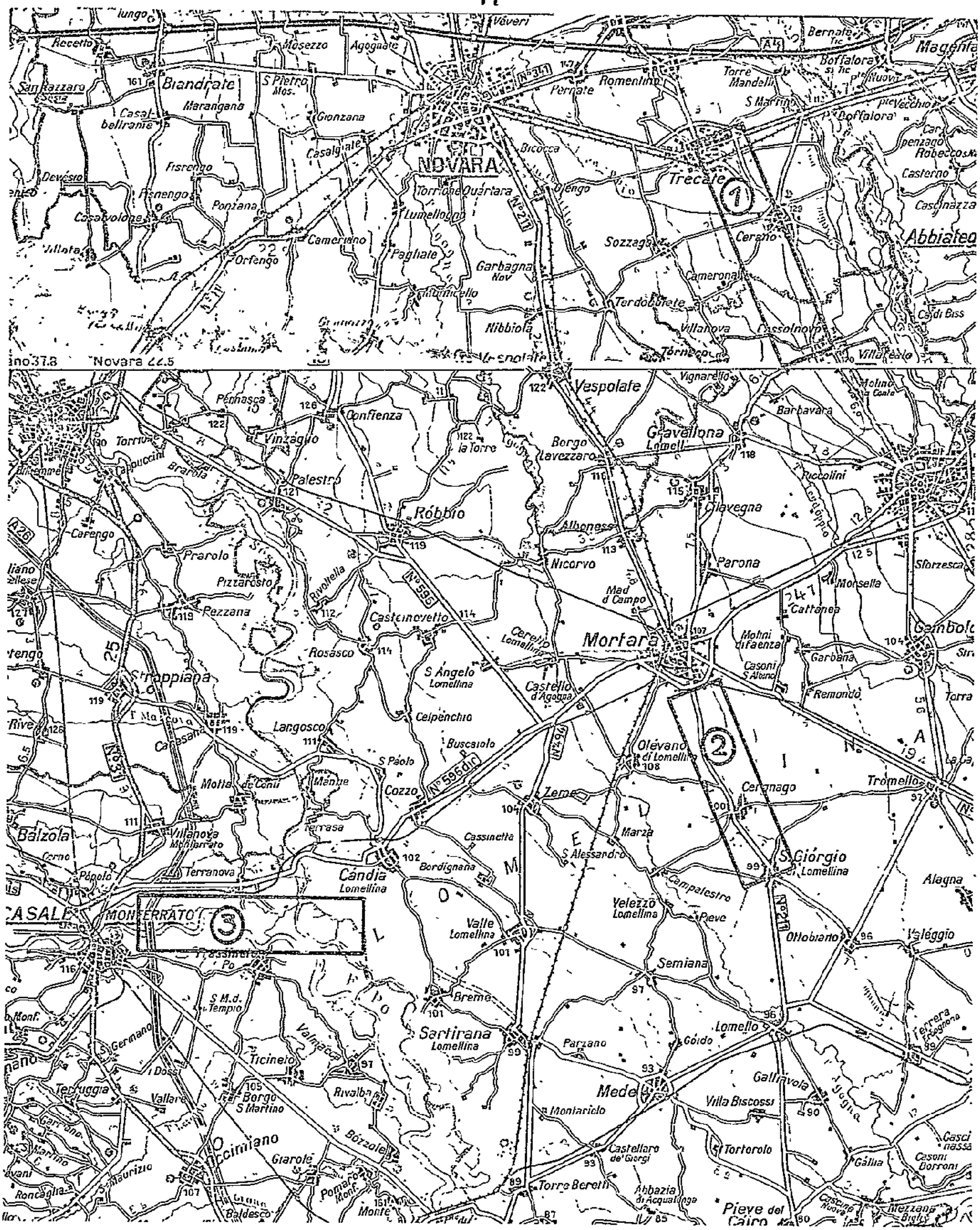

Fig. 7 : Location of the strips of data acquired by the Bendix M^2S scanner flight on August 7th 1975

Approx. scale: 1/200.000

Table 6 : Signification of symbols in Fig.8 and colours in Figs.9 and 10

	Class	Symbol in Fig.8	Colour in Figs.9 & 10	Class number in Table 7
Rice varieties	Balilla Grana Grossa	B.G.G.	Dark blue	5
	Gritna	G	Green	6
	Carnaroli	C	Red	7
	Rocca	Rc	Light blue	8
	Arborio	A	Violet	13, 14, 15
	Romeo	Ro	Orange	19, 20
Rice in general			White	1, 9, 11, 12
Corn		M	Yellow	16, 17, 18
Others		/////	Black/dark brown	2, 3, 4, 10

3.4.3.2 Discrimination of Rice Varieties[2]

Only some results are presented here. The work will continue during the coming months. The data used are contained in the strip no. 2 (see 3.4.3.1), to the south of Mortara, at an altitude of 5000 feet. This first study covers only a part of the prepared ground truth, which is sketched in Fig. 8. The classifier used assumes euclidian distance between the pixels to be classed and the mean vectors of the classes of interest, the distance to each class being divided by the standard deviation of the class distribution. Figs. 9 and 10 show the results in a qualitative way, each colour being attributed to a given class. They were obtained by photographing the classified maps displayed on the COMTAL screen. The significance of colours in Figs. 9 and 10 and symbols in Fig. 8 is given in Table 6 and the statistical parameters of the various classes are collected in Table 7.

As can be seen in Table 7 the calculations were made with 20 classes but for practical reasons some of the classes have been grouped under the

Table 7 : Statistical parameters of classes involved in classification process

Class Nr.	Chan. Nr.	2	3	4	5	6	7	8	9	10	11	$\sum_{i=2}^{11} \frac{\sigma_i}{\mu_i}$	Class description
1	μ	53.681	73.770	84.779	63.743	65.544	51.655	179.455	127.684	45.391	98.198	0.63	Rice unidentified var.
	v	4.125	9.015	19.014	9.085	14.520	10.236	63.043	33.796	98.640	6.647		
2	μ	50.807	64.679	70.715	56.804	62.611	47.416	136.259	99.717	32.264	95.883	0.63	poplars sample 1
	v	2.271	3.593	5.139	6.040	4.868	4.201	58.403	38.714	50.433	55.081		
3	μ	48.416	61.329	69.301	57.151	66.699	53.771	111.177	87.439	27.309	106.262	0.87	poplars sample2
	v	4.161	2.849	5.004	3.454	4.906	79.439	9.182	4.968	155.948	7.040		
4	μ	60.603	86.761	99.671	85.174	102.556	89.929	167.452	98.597	41.847	150.636	0.65	wet fields
	v	5.071	13.258	17.022	19.115	50.648	46.198	60.381	19.147	67.672	43.667		
5	μ	47.987	65.289	73.538	58.993	65.354	51.089	134.995	95.940	29.885	104.006	0.76	Rice BGG
	v	5.165	8.665	10.277	8.510	19.405	19.281	44.180	38.630	61.396	21.766		
6	μ	49.939	67.929	79.192	61.591	67.287	53.548	155.296	114.913	42.502	103.172	0.59	Rice - G
	v	3.153	2.221	4.307	13.607	4.162	3.454	95.669	14.735	119.432	6.228		
7	μ	47.448	66.195	77.439	61.646	68.418	53.419	138.296	90.445	27.390	103.128	0.60	Rice - C
	v	0.611	1.260	2.654	18.448	6.460	3.079	38.201	33.240	55.070	8.997		
8	μ	49.833	70.841	79.777	63.867	71.654	56.995	148.841	104.461	35.670	107.309	1.26	Rice. Rc
	v	22.691	51.791	67.311	69.176	141.414	132.023	100.942	64.324	73.423	76.992		
9	μ	48.092	67.332	76.224	60.840	67.307	52.849	146.233	103.709	34.668	104.886	1.10	Rice. (*) Composite
	v	13.493	28.517	41.201	35.929	62.725	59.755	158.154	90.367	80.157	37.039		
10	μ	51.165	71.477	81.002	67.492	78.748	64.797	139.856	94.144	33.320	120.878	1.91	Other(**) than rice
	v	39.009	115.331	178.483	130.223	215.796	240.951	742.387	189.833	169.222	319.070		
11	μ	44.838	62.181	71.826	57.181	61.702	47.375	149.065	106.312	36.245	101.640	0.78	Rice-Balilla
	v	2.025	4.613	8.463	11.198	19.629	16.368	28.219	46.069	103.457	8.590		
12	μ	44.443	65.924	77.101	60.751	66.048	51.388	153.645	102.947	33.387	103.747	0.51	Rice-Roma
	v	1.735	2.790	6.961	4.259	10.657	6.644	37.736	22.374	34.800	6.346		
13	μ	50.743	71.875	83.728	65.860	71.953	57.510	166.610	111.548	39.208	107.065	0.35	Rice. A sample 1
	v	0.492	0.831	1.447	1.629	2.121	2.010	5.532	6.920	49.243	6.231		
14	μ	43.576	62.692	70.178	56.629	61.440	46.724	150.965	112.786	38.942	103.332	0.44	Rice. A sample 2
	v	3.236	1.573	3.971	4.602	2.476	3.115	6.106	8.694	47.286	9.490		
15	μ	50.717	70.285	83.413	65.828	71.792	57.113	161.526	117.231	44.901	110.366	0.36	Rice. A sample 3
	v	0.539	1.410	3.453	2.460	2.557	2.219	18.548	12.192	49.219	4.951		
16	μ	50.357	69.698	81.364	64.743	71.591	57.916	177.469	118.590	46.574	113.163	0.37	Corn sample 1
	v	0.939	2.306	6.018	3.930	5.757	7.763	137.877	55.841	100.305	8.887		
17	μ	54.607	73.971	84.250	69.932	81.715	66.487	145.274	97.549	35.243	120.769	0.77	Corn sample 2
	v	4.294	12.169	18.016	21.274	45.406	38.836	68.381	32.009	66.639	21.355		
18	μ	52.634	66.506	73.524	61.050	71.327	55.639	121.347	92.068	31.764	114.556	0.42	Corn sample 3
	v	0.860	1.110	1.559	20.649	2.620	2.827	4.182	2.618	30.776	10.543		
19	μ	44.189	62.984	72.602	56.345	59.093	44.989	153.031	109.522	39.039	95.803	0.85	Rice Ro Sample 1
	v	0.798	1.023	1.624	1.096	1.143	1.414	8.672	12.458	659.897	6.057		
20	μ	41.983	62.323	73.133	59.499	65.330	52.106	147.780	97.271	29.036	103.490	0.64	Rice Ro sample 2
	v	1.300	3.705	12.271	6.634	6.988	6.453	136.629	48.640	42.457	8.836		

μ : mean value of each channel over the proper training sample

v : variance of the same data

$\sum_{i=2}^{11} \frac{\sigma_i}{\mu_i}$: weighted standard deviation for each class, where $\sigma = (v)^{1/2}$

* *Rice varieties BGG, G, C, Rc and A sampled together*

** *Wet fields, corn and uncultivated areas sampled together* same colour on Figs. 9 and 10. In particular the white colour covers all the rice varieties which were not sampled on the area processed here (i.e. classes no. 1, 11 and 12 in Table 7) and a composite rice class - no. 9 - composed by sampling together the rice varieties sampled in the area, i.e. BGG, G, C, Rc and A). The black/dark brown colour, on the other hand, covers a composite class made up by sampling together wet meadows, corn and uncultivated zones (class no. 10), and poplars and wet meadows present as distinct classes (class no. 2, 3 and 4).

The sampling was made on small portions of the fields labelled with the appropriate symbols on the area processed (Fig. 8) or outside the area for classes no. 1, 11 and 12.

The data from channel 1 were not used, due to an unacceptable level of noise. The calculations were made without any membership threshold for the classes, therefore no point was left unclassified.
In Fig. 9 the data were processed without correcting the channel values for the atmospheric effect due to the scan angle (100° angle from edge to edge of the swath). In Fig. 10 the data were corrected from this effect with the so-called "long track averaging" technique with, as a result, a better discrimination between rice and corn on the one hand, and rice and "others" on the other hand.

An overall examination of the classifications displayed show a partial discrimination of rice varieties with somewhat better results in Fig. 10. Variety BGG is rather well-recognized but outside its limits is confused with variety C; partial confusion occurs between varieties G and A whereas Ro is poorly recognized and Rc is not recognized at all.
Corn discrimination is also rather good in Fig. 10 (with atmospheric correction).
The above comments on rice varieties discrimination are obviously valid only for those rice fields whose variety is identified on the ground truth. The other rice fields, not labelled on the ground truth, contain unidentified varieties or a mixture of varieties. It must also be noted that confusion occurs between rice and non-rice, outside the rice region to the right of the area studied.

These qualitative results must be considered to be preliminary. It is hoped to make improvements by further refining the atmospheric correction technique currently under study, the sampling procedure and the classification algorithm. A quantization of the ground truth will enable us on the other hand, to present quantitative results under the form of a confusion matrix. On the other hand, the data from the higher flight (13,000 feet) will also be used and the effect of the loss in spatial resolution will be investigated.

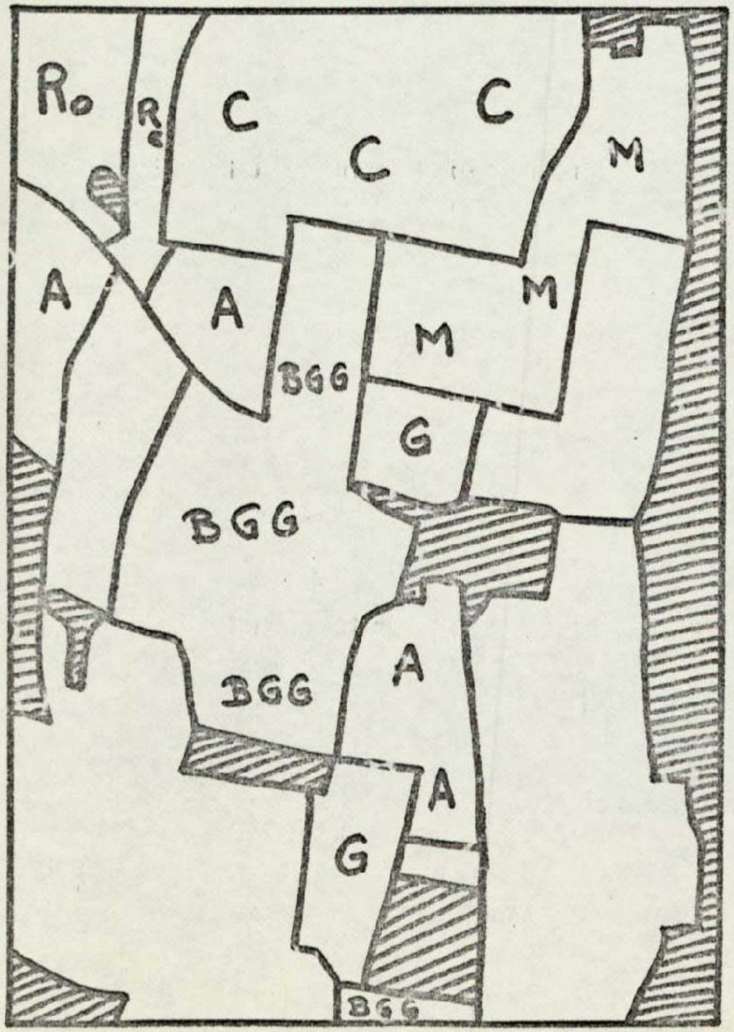

Fig. 8 : Ground-truth for rice varieties
Approx. scale $^{1}/_{15.000}$

Fig. 9 : Classification results for rice varieties without atmospheric correction on the data

13a

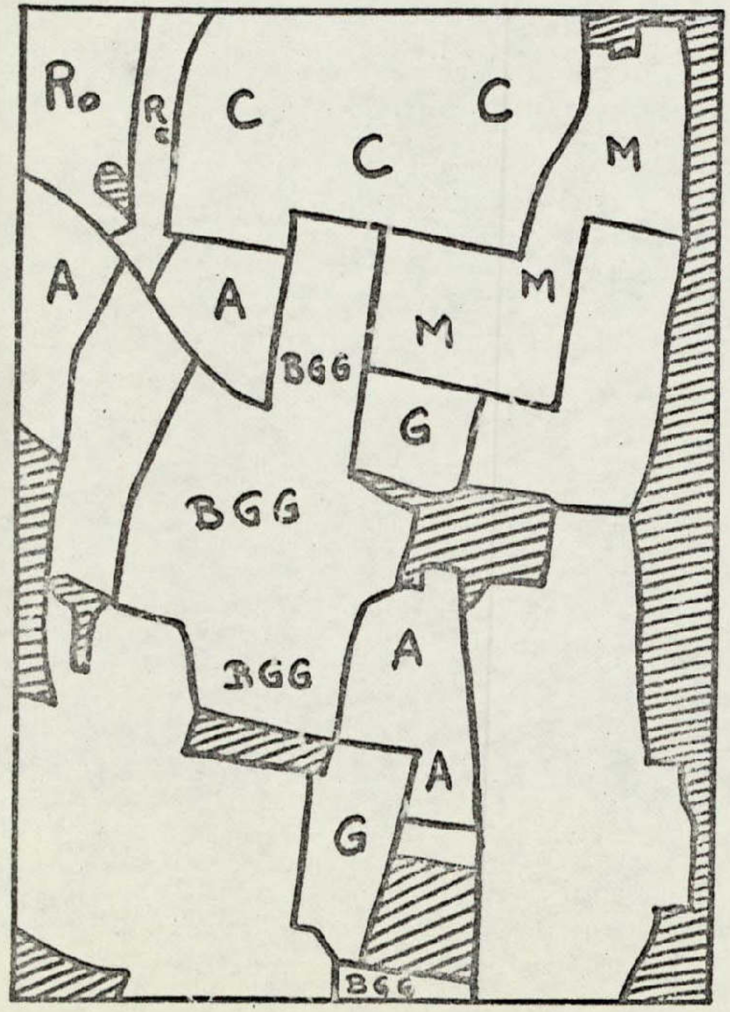

Fig. 8 : **Ground truth for rice varieties**

Approx. scale $^{1}/15.000$

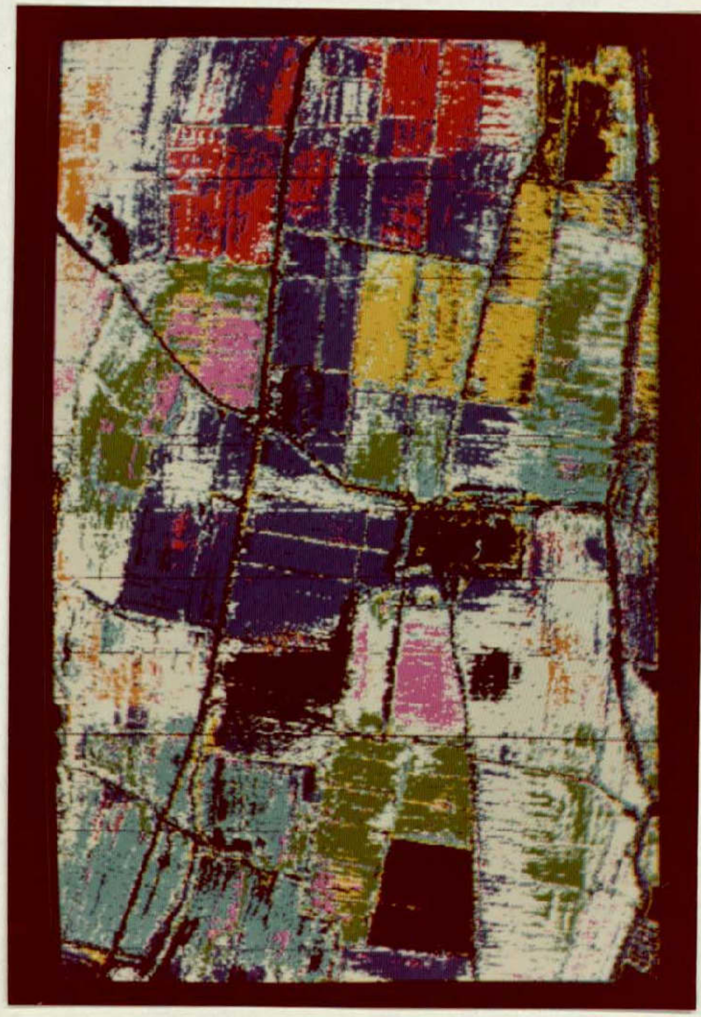

Fig. 10 : **Classification results for rice varieties after correction of the data from atmospheric effect**

13B

3.4.4 Computer-aided Interpretation of Satellite Data. Classification of Natural Beech Forests

Two LANDSAT scenes were free of clouds over the studied region, namely those of July 3, 1975 and September 13, 1975.
These two scenes were treated first by level-slicing on channel 7 in order to facilitate the recognition of geographic details.

Supervised methods of classification have been the most widely used. Signatures have been determined by making statistics over homogeneous regions.

Two classed of beeches were considered. One in sunlight and one in shadow. Even though chestnuts were of no direct interest to the AGRESTE Project, they had to be included in the classification because their signature is so close to that of beeches that misclassification could easily occur between these two species. Meadows covering the bottom of the valleys were also included. Automatic classification was then produced by different methods based either on Euclidean distance: a pixel is classified in the "nearest" class, or on the maximum likelihood principle: the pixel is classified in the class to which it has the highest probability to belong.
As the ground truth was not exhaustive (more than 50% of the surface is not characterized), the classification methods must use thresholds i.e. limits of distance or probability over or under which a pixel is not classified.

The best results were obtained by a maximum likelihood method (PARAM program): the results from July 3 are displayed in Fig. 12 and those of September 13 in Fig. 13.
Qualitative comparison with the geographic map reproduced schematically in Fig. 11 is quite good, and most of the beech forests are correctly identified.

In the scene of July 3, it is possible to separate beeches (red) from chestnuts (blue). Small isolated chestnut woods in the valley-bottom meadows are also identified.

The scene of September 13 confirms the results but here the discrimination between beeches and chestnuts is not so good, probably due to a less favourable period of vegetation. Fig. 14 shows a comparison of the two scene-classifications. The comparison is made on entirely deciduous forests i.e. beeches + chestnuts, blue corresponds to the classification of July3, red to the classification of September 13. Purple, the superimposition of these two colours, gives the intersection of the two classifications i.e. the pixels classified in the same way on both scenes. It can be seen that correspondence is quite good.

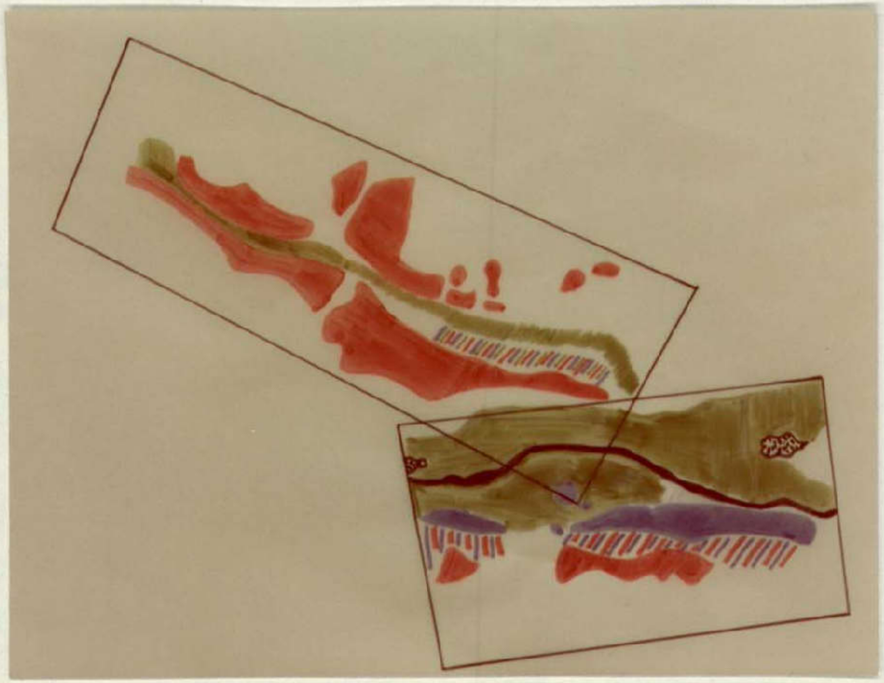

Fig. 11 : Ground truth reported from aerial photos

red: beeches
blue: chesnuts
green: meadows
white: not characterised

The river "Stura di Demonte" and the villages of Demonte (east) and Aisone (west) are reported to facilitate localisation

Scale is about 1 cm = 1.2 km

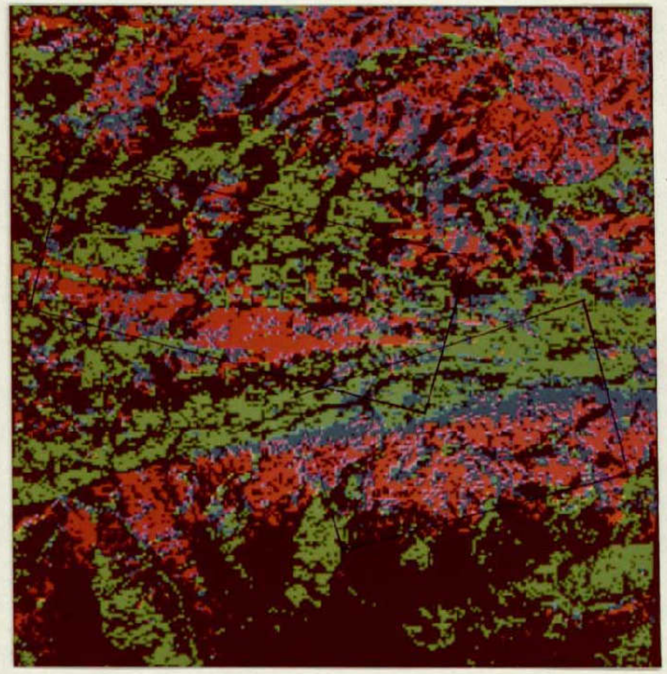

Fig. 12 : Results of parametric classification

red: beeches
blue: chesnuts
green: meadows
black: not classified

The frames on the figure correspond to those of ground truth

Scale is about 1 cm = 2.2 km

14B

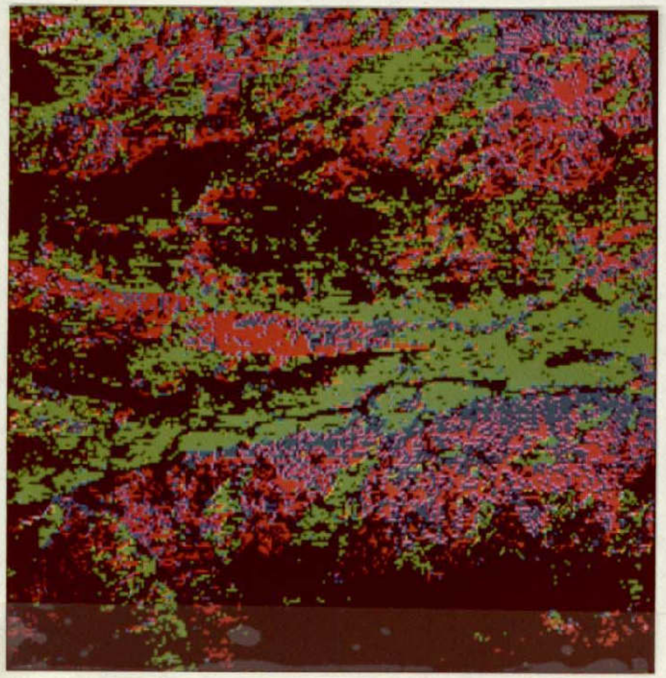

Fig. 13 : Results of parametric classification of September 13th

red: beeches
blue: chesnuts
green: meadows
black: not classified

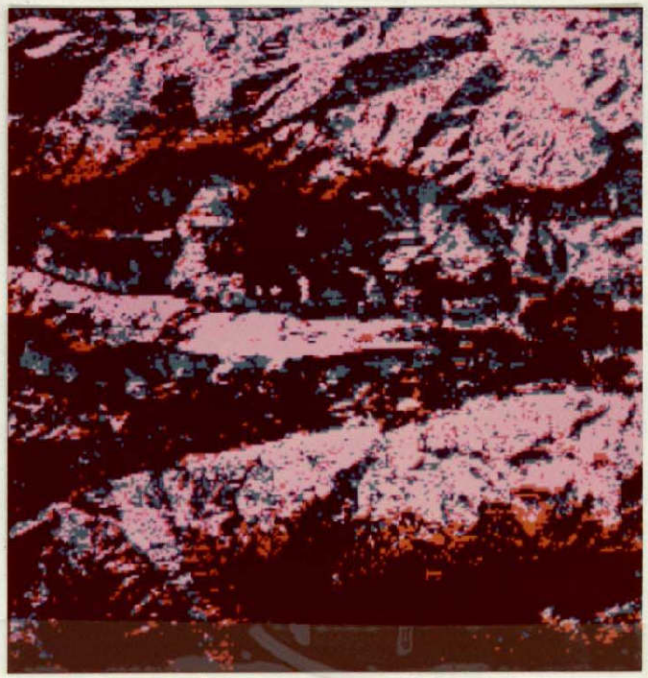

Fig. 14 : Comparison of classifications of June 3rd and September 13th

Comparison is made on total deciduous forest :
purple: zone classified on both scenes
blue: zone classified only on June 3rd
red: zone classified only on September 13th

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Due to the lack of an exhaustive ground truth, quantitative comparisons are not easy. In fact, the level of the threshold used for each class is one of the important parameters for the final population of the class. Up to now, the thresholds have been fixed empirically taking into account the variance-covariance matrix of each class.

LIST OF REFERENCES

[1] G. M. SUITS: "The Calculation of the Directional Reflectance of a Vegetative Canopy", Mich. Symp., 1972, 117-125 (1972)

[2] M. BAGLIANI - Work done at the JRC-Ispra in the Framework of Collaboration with IGL (1976)

[3] LANDSAT-2 Satellite Follow-on Investigation no. 28790 - Agricultural Resources Investigations in Northern Italy and Southern France - 3rd QPR, February 15-May 15, 1976

[4] B. STURM, J. HERZOG: "Preprocessing Algorithms for Radiometric Corrections and Texture Spatial Features in Automatic Land-Use Classification", IX Mich. Symp., (1976)

[5] G. LA PIETRA, J. MEGIER: "Acreage Estimation of Poplar Planted Areas from LANDSAT Satellite Data in Northern Italy", Int. Union of Forestry Organizations, XVI IUFRO World Congress, Oslo, June 20-July 2 (1976)